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THE SOURCES OF APPLE BITTER-ROT INFECTIONS.

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CONTENTS.

INTRODUCTION.

In the more southern apple-growing sections of the United States the disease having the common name bitter-rot or ripe-rot and caused by the fungus *Glomerella cingulata* is one of the most destructive with which growers have to contend. In some seasons it is undoubtedly the most destructive. The financial loss from apple bitter-rot is increased by the fact that whereas such diseases as scab, blotch, and blight destroy the crop in early spring or prevent its setting at all, bitter-rot does not ordinarily begin until July and usually does not complete its ravages until September or even later. The grower, then, may during the early part of the season spend his time and money spraying for the control of other diseases, such as scab and blotch, and of insect pests, only to see his fruit finally succumb to bitter-rot in midseason, often despite his best efforts to prevent it. As compared with the control of scab and blotch, which are also important apple diseases in the South, the control of bitter-rot is difficult of accomplishment. In the case of scab and blotch, definite times can be set for the application of sprays for control

purposes, since these diseases appear only in the early part of the season when the apple is in a definite stage of development. With bitter-rot, however, infections may occur from about June 15 until well into September. If the weather is hot and moist and sources of infection are present in sufficient numbers, the whole crop may be destroyed within a week, almost before the orchardist is aware that the disease has broken out. The writer has seen cases in which the grower on visiting his orchard for the purpose of inspecting the crop preparatory to picking has been surprised to find every apple rendered worthless by bitter-rot, while only a few days before the crop had appeared to be entirely free from disease. Naturally such experiences as this cause southern growers to dread this rot more than any other disease affecting the apple, with the possible exception of pear blight.

Estimates of the annual losses caused by apple bitter-rot are very difficult to make with any degree of accuracy because of the great seasonal variation of the disease, due mainly to weather conditions and because of the variation in the amount of damage done in different sections from year to year. Local conditions also play a great part in the variations of this disease. A local shower on a hot July afternoon may supply just the right conditions of extreme heat and moisture to give the disease a beginning which finally may lead to the total destruction of the apple crop, whereas a few miles away conditions may be such that the disease is unable to gain headway all season.

Although the causal fungus is found in apple-growing sections of States farther north and also in Europe and Australia, bitter-rot is a serious disease only in the more southern apple-growing sections of this country. Apparently the fungus is to be found in practically every section of the world in which apples are grown, but is capable of causing very serious losses only under the warm moist weather conditions of the southern apple-growing sections of the United States. According to Edgerton (7)[1] and Schneider-Orelli (11), the fungus as it occurs in the northern United States and in Europe is physiologically different from the fungus associated with the serious bitter-rot of the Southern States.

Bitter-rot is typically a hot-weather disease. Accordingly, the hot weather of the South coupled with sufficient moisture for germination of the spores is peculiarly favorable to its development. Ideal weather for bitter-rot infections is furnished by high temperature and high humidity with the interspersion of frequent showers.

The earliest reference to apple bitter-rot is usually credited to Berkeley (2) in 1856, but Ricker (9) in 1916 discovered a reference

[1] The serial numbers in parentheses refer to "Literature cited," at the end of this bulletin.

to it in an unpublished manuscript by Coxe, dated May 30, 1829. In this manuscript, apple bitter-rot is referred to as being a common disease, and slaked lime placed about the tree is mentioned as having been advised as a remedial measure.

The fungus which causes bitter-rot of the fruit also causes a canker of apple branches. As the branch cankers are chiefly important as sources of rot infection, they will be described and discussed under the head "Sources of infection."

The time of appearance of the rot depends upon weather conditions primarily, although it also depends to some extent upon the condition of the fruit and the proximity and number of sources of infection. The fruits of susceptible varieties may be infected even when they are quite young and green, provided the weather is hot and moist and sources of infection are present. On the other hand, some varieties are not easily infected until midseason except under extremely favorable conditions.

Where the sources of infection are particularly abundant, the disease may gain some headway even during seasons in which the weather is relatively unfavorable for its development.

Glomerella cingulata (Stoneman) Spaulding and Von Schrenk, a fungus having an ascogenous, or "perfect," form and a conidial, or "imperfect," form, is the casual organism involved in the production of apple bitter-rot. The most common fruiting stage is the Gloeosporium, or conidial, the so-called "imperfect," stage.

The conidial masses, or acervuli (Pl. I, figs. 4, 5, and 6), when newly formed are pink and mucilaginous or thinly gelatinous. Later, however, upon drying they become dark colored and of a hard, horny consistency. It is through the agency of the conidia that nearly all of the damage to the fruit of the apple is brought about. The gelatinous nature of the conidial masses when wet and their horny consistency when dry prevent the dissemination of the conidia by the wind, but raindrops can spatter them about and especially upon the apples located below infected fruit. Excessive moisture can also cause the conidial masses to trickle or drip down, and here the wind may play a part in modifying the direction of their downward course.

Birds probably play some part in the dissemination of conidia, but a much more important part is played by insects, more especially by flies. Clinton (6) in 1902 first showed that the disease could be disseminated by flies. The writer has often observed flies which, after alighting upon infected fruits and coming in contact with the mucilaginous spore masses, have flown and alighted upon sound apples upon the same and other trees.

As noted by Burrill and Blair (4) in 1902, conidia embedded in the horny mass of the acervulus, if kept dry, retain their vitality during

many weeks and even months, but when once suspended in water subsequent drying kills them. These observations have several times been confirmed by the writer.

The ascogenous stage (Pl. I, figs. 1, 2, and 3) is not very easily found in nature or, if found, is rather difficult to identify, owing to the frailness and consequent evanescence of the asci. Clinton (6) in 1902 and Von Schrenk and Spaulding (12) in 1903 succeeded in finding it in diseased fruits and cankers, respectively. The writer has also found this stage in bitter-rot mummies, in cankers caused by the bitter-rot fungus, and in cankers caused by other agencies.

SOURCES OF INFECTION.

MUMMIED FRUITS.

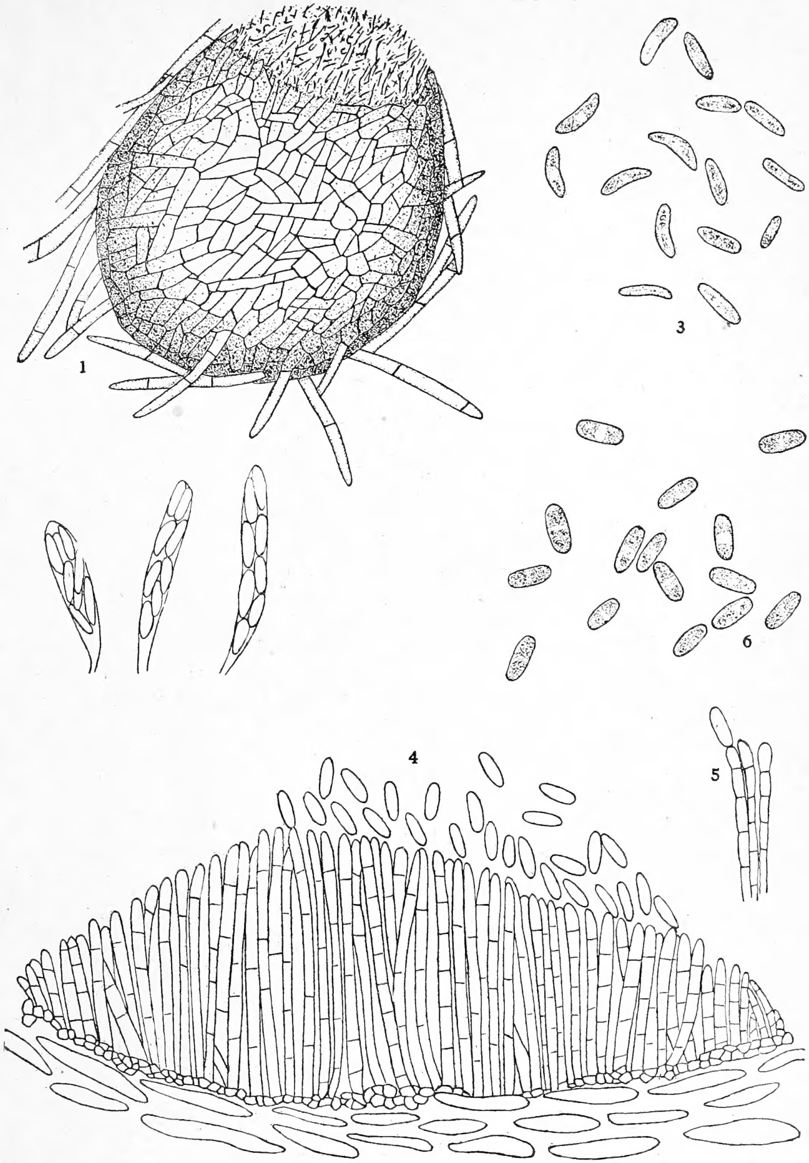
The mummied or rotten fruits which have remained upon the tree or upon the ground since the preceding autumn constitute one of the most important sources for the infection of the fruit of the current year (Pl. II, fig. 1). Often, especially in the eastern United States, they are by far the most important means by which the fungus is carried over from one season to another.

Clinton (6) in 1902 showed that the fungus could live through the winter in mummied fruits. He states—

> However, in the fall and succeeding spring on the mummy apples, the fungus, as a saprophyte, gives rise to the permanent or Gnomoniopsis (Glomerella) spore stage. The Gloeosporium spores that have not been carried away disappear through germination, and more or less of a mat of fungus thread covers the apple. Protected by this, perithecia that develop asci, with ascopores, which evidently came to maturity the next summer, are gradually developed in a stroma. These ascospores are shed out of the asci and perithecia when mature and are then scarcely to be distinguished from the Gloeosporium spores. No doubt they are carried by the pomaceous flies to the green apples and thus start the disease again for another year.

As recorded by Burrill and Blair (4), Hasselbring did not find the second spore forms, described by Clinton, on mummied apples kept out of doors, but he found that the fungus ordinarily retains its vitality in a dormant state in winter, and in May or later under proper conditions begins to produce again the same kind of spores, borne on fertile threads of the fungus, in the same manner as it did the preceding summer. Spores secured from old mummies were inoculated into green apples and produced typical bitter-rot spots. This was repeated with spores from bitter-rot mummies collected in different orchards, and was found to be an easy procedure. Burrill and Blair add—

> The spring infection may therefore start from these old apples, and recent observations in the field have given indisputable evidence that it does sometimes so occur.



MICROSCOPIC CHARACTERS OF THE APPLE BITTER-ROT FUNGUS.

FIG. 1.—A perithecium from an artificial culture of *Glomerella cingulata* isolated from a canker caused by *Phyllosticta solitaria*. × 350.

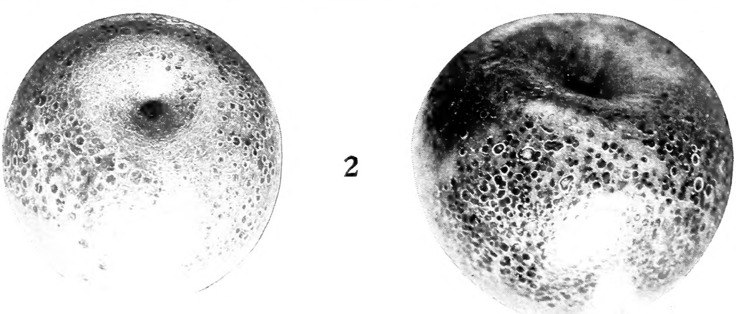
FIG. 2.—Asci from a perithecium obtained in the same manner as that shown in figure 1. × 350.

FIG. 3.—Ascospores from asci obtained in the same manner as those shown in figure 2. × 425.

FIG. 4.—Section through an acervulus from a bitter-rot spot on a Ben Davis apple artificially produced through the agency of spores from pure cultures of the fungus. The cultures were made from conidia obtained from a bitter-rot canker. × 350.

FIG. 5.—Conidiophores and a conidium from the acervulus shown in figure 4. × 350.

FIG. 6.—Conidia from the acervulus shown in figure 4. × 425.



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APPLES AFFECTED WITH BITTER-ROT.

FIG. 1.—An apple affected with bitter-rot and, just above it, a mummied apple of the preceding season. Spores washed down from the mummy have infected the previously sound apple. Variety, Yellow Newtown. Greenwood, Va., 1916.

FIG. 2.—Apples with the "peppered" appearance caused by many infections. These small blisterlike spots were due to infection by spores coming directly from a bitter-rot canker. Variety, Missouri. Bentonville, Ark., 1914.

Von Schrenk and Spaulding (13) in 1903, after investigations carried on in Missouri, state—

> Another source of infection is found in the dried mummies hanging on the trees and lying on the ground under the trees. The diseased apples of one season either fall to the ground (most of them do) or they remain on the trees, where they dry and shrivel up. When examined in the spring many of these mummified fruits are found to contain spores of the bitter-rot fungus in quantity.

Again they state—

> It was formerly supposed that the fungus passed the winter in the mummies, but as most of these were on the ground it was difficult to understand how the apples high up in the trees became infected. It now seems probable that the mummies play a comparatively small part in serving as distributing points for spores from year to year.

In 1902, Alwood (1), as the result of observations and experiments in Virginia, came to the conclusion that the mummied fruits on the tree and the rotted fruits on the ground were the chief sources of infection. He states—

> It appears to be well established that the mummied fruits hanging to the trees and the rotten fruits upon the soil constitute in large measure the source of the annually recurring infection. To my mind these fruits are *the source* of infection.

Scott (14, p. 12) in 1906, in his discussion of sources of infection, states—

> The results [of observations made in Virginia and West Virginia orchards] lead to the conclusion that the overwintering mummies hanging on the trees constitute the chief source of infection, at least in this particular region. In the majority of cases examined, a mummy could be found in the upper portion of the infected area.

Burrill (3) in 1907 considered that mummies on the ground rarely acted as infection sources.

The writer (10) in 1915, as the results of investigations in the Ozarks of Arkansas, stated—

> Masses of spores were also obtained many times from mummies, and where mummies are present they undoubtedly are important sources of infection. In many of the badly infected orchards, however, they had been removed both from the trees and from the ground.

It will be noted that eastern investigators consider mummied and rotted fruits as the principal means by which the fungus is carried over from season to season. Investigators working in the Middle West, however, consider them as of only secondary importance in the survival of the fungus through the winter.

The writer during the past three years has examined mummied and rotted fruits of previous seasons from orchards in Virginia and in Arkansas. In both mummies and rotted fruits of the preceding

year the fungus is usually to be found. However, neither furnished a good medium for the fungus, and as a result the number of spores (usually conidia) produced is quite small compared with the number which the fungus produces when growing in a newly rotted fruit of the current season. The size of the spores is usually somewhat reduced also.

A mummy hanging on a tree furnishes a medium which is deficient in moisture and in plant food. In the case of the rotted apples on the ground the bitter-rot fungus must compete with many of the mold and rot fungi and bacteria which are less susceptible to cold and which are true saprophytes. In examining rotted fruits, one finds a mixture of the spores of the bitter-rot fungus and those of various molds, together with numerous bacteria.

In both Virginia and Arkansas orchards, mummies and rotted fruits undoubtedly are important sources of infection. The writer has examined infected orchards in Arkansas in which bitter-rot mummies and rotted fruits of the preceding year were abundant in the trees and on the ground and in which no other sources of infection could be found. Some of the most seriously infected orchards which the writer has seen, however, were Arkansas orchards from which the mummies and rotted fruit had been removed. Generally, in Arkansas few mummies are to be found in the trees, and as nearly all growers practice clean cultivation throughout the earlier part of the season those which have fallen to the ground have been turned under. It has been a common practice, too, for the grower to gather up and haul to evaporating plants the best of the dropped fruit and to sell the rotten and diseased fruit to the distilleries.

The writer agrees with Alwood and Scott that mummies are the chief sources of infection in the orchards of Virginia. In that State the Yellow Newtown variety, known locally as the Albemarle Pippin, is the commercial variety which is damaged to the greatest extent by the disease. This variety is grown for the most part in coves of the Blue Ridge, situations which usually do not admit of cultivation. These trees do not come into bearing until they are about 15 years old, and they are very long lived. Accordingly, most of them are rather old and quite large. The dropped fruits have no economic value. There are many reasons, therefore, why rotted fruits should be left on the ground. There are usually some mummies also to be found hanging on trees of such size. The writer counted more than a hundred on one tree, which, however, was an unusual number. In Virginia he was easily able to trace the source of clumps of rotted fruits to mummies hanging in the trees. This is readily done if examination is made shortly after the first outbreak of the disease.

In many Virginia orchards the lower limbs when laden with fruit reach to the ground. In such cases the disease could be found first on the fruits in contact with those of the previous season on the ground. From these infected fruits spores could easily be carried to sound ones.

The writer has frequently attempted to find the fungus in mummies and rotted fruits which were more than a year old, but has been uniformly unsuccessful. Those upon the trees appear to be dried up so thoroughly at the end of a year that they drop from the tree; those on the ground finally become almost wholly disintegrated through the action of molds and bacteria.

In Virginia, therefore, mummies and rotted fruits, being more prevalent, are of more importance as sources of infection than they are in Missouri and Arkansas. In the last-named States cankers may overshadow them in importance.

BITTER-ROT CANKERS.

REVIEW OF THE LITERATURE.

In 1902 R. A. Simpson discovered that in Illinois a certain type of canker was associated with outbreaks of bitter-rot. He found that if search was made shortly after the first outbreak of the disease such cankers were to be found just above a clump of infected fruits. Simpson's discovery was announced at about the same time by Burrill and Blair (4) and by Von Schrenk and Spaulding (13).

Burrill and Blair (4) in 1902 stated that Hasselbring had shown the fungus found in these cankers to be identical with the bitter-rot fungus. Hasselbring found that the fungus from the cankers would cause typical bitter-rot when introduced into sound apples.

Von Schrenk and Spaulding (13) in 1903 also showed that spores from the cankers could cause typical bitter-rot when introduced into sound apples. They further showed that spores could be washed from the cankers by water and that when falling upon apples they could produce bitter-rot. To determine whether or not the Glomerella could actually be the causal organism involved in the production of cankers, they inoculated sound branches with spores (conidia) from pure cultures. As a result of these inoculations cankers were formed which showed the characters of the cankers found by Simpson. From these artificial cankers Von Schrenk and Spaulding reisolated the fungus and also inoculated apples with conidia produced in the cankers. They describe the development of the artificially produced cankers as follows:

> Several weeks elapsed before there was any evidence of development on the limbs. In both the inoculated slits and tne control slits the bark dried somewhat along the edges of the slit, making a gaping wound. After some

two weeks a distinct callous layer had formed under the edges of the control slits. The two callous layers joined after six to eight weeks and occluded the wound. In the slits where bitter-rot spores had been inserted the callous formation was less marked. The exposed wood turned dark, almost black, and the exposed edges of the bark turned back. The living bark then began to dry out gradually and became depressed, and after about two months a decided, sharply defined depressed area had formed, with the slit in the center. Shortly thereafter small black pustules broke through the dried bark in a number of instances. By that time the infected points showed all the characteristics of small cankers. On examination the black pustules were found to contain masses of spores resembling those of the bitter-rot fungus.

Alwood (1) in 1902, while admitting that cankers may be the chief sources of infection in Illinois and Missouri, as stated by Burrill and Blair (4) and by Von Schrenk and Spaulding (13), did not think that these statements applied in Virginia. He stated—

> In no instance have we been able to find the presence of the bitter-rot fungus on the limbs or trunks of apple or pear, though we have especially watched for its occurrence.

Scott (14) in 1906 made the following statements:

> Limb cankers occur abundantly in Virginia orchards, but the writer has so far been unable to find the bitter-rot fungus associated with any of them . . . in no case was there found associated with such outbreaks any cankers that could be identified as bitter-rot cankers.

Burrill (3) in 1907 stated that a wound is necessary for the beginning of a canker and that cankers may live sometimes for two or even three years.

The writer (10) in 1915, reporting on work carried on in Arkansas, stated—

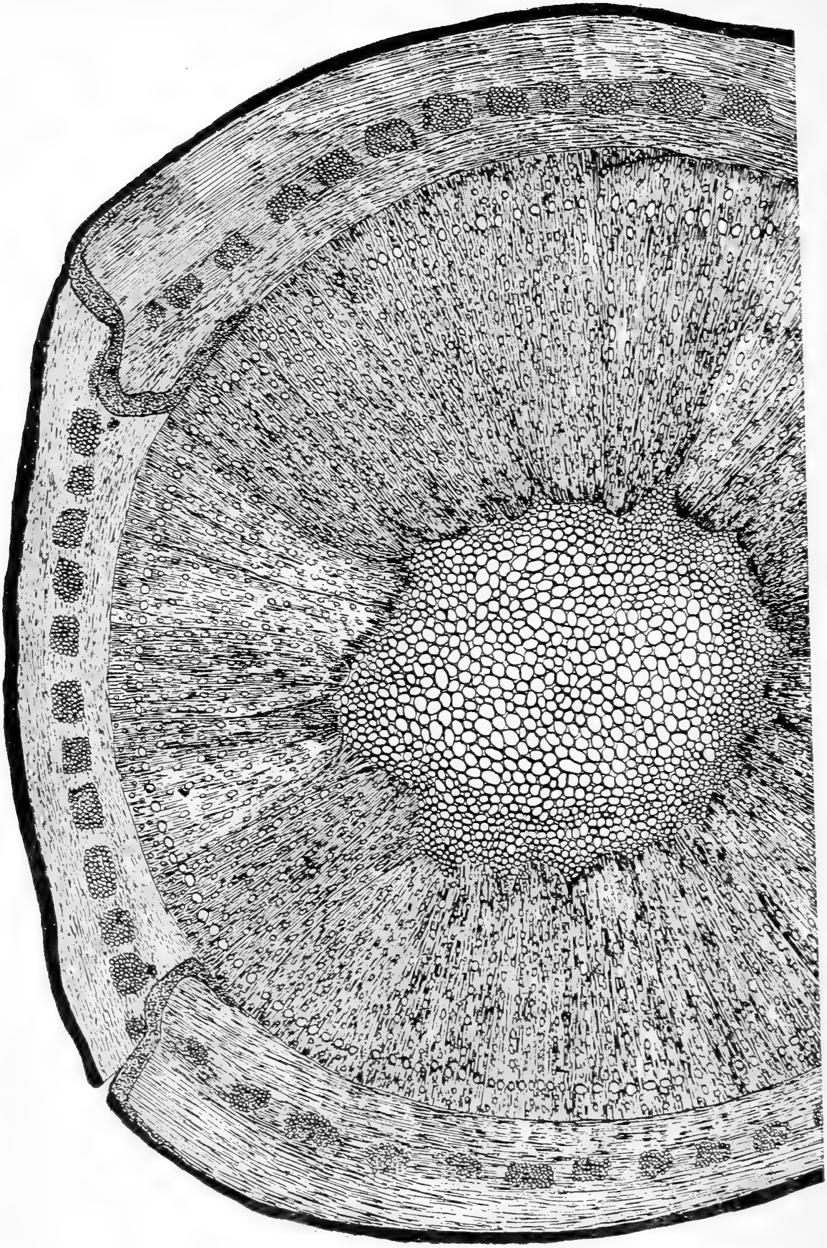
> On May 15, a cankered limb from the second orchard was brought into the laboratory and kept in a moist chamber for 24 hours. This canker resembled in every way the limb cankers as described and figured by Burrill and Blair and Von Schrenk and Spaulding. It was a black, sunken oval area with many slight rifts or cracks in the bark through which, after the limb had remained in a moist chamber for 24 hours, an abundance of the characteristic pink acervuli appeared. Near the center of this canker was a small dead spur through which infection probably took place. Cankers resembling in every way published descriptions and figures of bitter-rot were also collected on June 3 and many times thereafter.

Previous to his experiences with bitter-rot cankers in Arkansas, the writer had attempted at various times to find them in Virginia, but without success. Thinking that his familiarity with the appearance of the cankers in the West might aid him in the search, he again attempted to find them in Virginia in 1916 but was unsuccessful.

It seems therefore rather well demonstrated that whereas bitter-rot cankers are of quite common occurrence in the Middle West, they are rarely to be found or are wholly wanting in the East. The

BITTER-ROT CANKERS ON APPLE BRANCHES OF VARIOUS AGES.

Each of these cankers was located above a clump of rotted fruits and was producing spores in immense numbers. The varieties are Givens, Jonathan, and Ben Davis. Bentonville, Ark., 1915.



SECTION THROUGH A BITTER-ROT CANKER ARTIFICIALLY PRODUCED ON A YOUNG BRANCH OF A BEN DAVIS APPLE TREE.

The reaction of the host is shown in the formation of a callus layer. The dead bark remains attached to the dead and shrunken wood. × 32.

writer is unable to find a record of a bitter-rot canker occurring in eastern orchards.

DESCRIPTION OF CANKERS.

The cankers caused by *Glomerella cingulata* (Pl. III) are fairly characteristic and are not easily confused with any other cankers except those caused by the pear-blight organism (*Bacillus amylovorus*). Especially on varieties which have suffered severely from pear blight, bitter-rot cankers and pear-blight cankers are sometimes hard to differentiate. The writer does not doubt that in the past bitter-rot cankers have many times been mistaken for pear-blight cankers.

The bitter-rot canker consists of a sunken portion of bark, usually somewhat oval in outline, beneath which the wood is dead and dry. The dead bark and cambium adhere rather firmly to the wood, and in older cankers more or less complete cracks or fissures parallel to the edges of the cankers give a zoned effect to the dead bark. The depression (Pl. IV), too, in older cankers becomes much more pronounced, owing to the fact that because of the death of the cambium there has been no increase in the thickness of the branch in the infected area. The wood and medullary rays, even in the case of young cankers, are colored brown all the way into the pith. Often the canker is surrounded by a layer of callus (Pl. IV), which successfully prevents further extension of the canker and which eventually entirely obliterates the old lesion.

In many cankers a small dead twig will be found directly in the center of the blackened area, doubtless explaining the mode of entrance of the fungus. Sometimes this dead twig is the remains of a fruit spur, but often it is a water sprout, part of which has been broken off.

Cankers are usually found on branches which are at least 2 years of age. The writer has found them on branches which range in age from 2 to about 15 years, but has never been able to find them on young vigorously growing twigs less than 2 years of age.

The number of cankers per tree is usually few, even in orchards in which the disease has been very serious for a number of years. However, in the case of especially susceptible varieties, such as Givens, the writer has found trees having more than 30 large bitter-rot cankers, besides numerous small ones.

At first thought it would seem that cankers, being located on older branches and hence near the center of the tree, are not advantageously located for the infection of fruits, but as the apples develop and bend the branches downward the position of the cankers is often directly above that of large numbers of the apples. Plate II, figure 2, shows young fruits badly infected from cankers thus located.

LIFE HISTORY.

In the literature pertaining to bitter-rot cankers there is very little to be found on the subject of their development and length of life. Spaulding and Von Schrenk (13) state—

> The majority of the cankers found during the last summer probably were started two years ago. During the first year the fungus made very little headway. A very small central area was killed, generally around and including a small branch. The following year the large part of the canker was formed. Whether the cankers will continue to increase in size is as yet undetermined, but it does not seem probable, for if such were the case cankers 3 or more years old ought to have been secured in the orchards where the bitter-rot has been common for many years.

On many varieties the writer has not been able to find any very old cankers, but in the case of very susceptible varieties, such as Givens, he has found many cankers which have attained apparent ages of 8, 10, and more years. One limb, which by count of annual rings was 13 years old, bore a canker which showed 11 zones, indicating that the canker had passed through 11 growing seasons. Cankers were found growing on main limbs which were evidently much older than this. In order to trace the development of cankers, the writer in 1914 made some preliminary inoculations of apple branches with spores from pure cultures of *Glomerella cingulata*. Inoculations were made by introducing newly formed conidia into small slits artificially made in the bark. The slits were at once covered with absorbent cotton moistened with distilled water, which was allowed to remain for one week. Controls consisted of branches similarly treated except that no conidia were placed in the slits.

In Arkansas on September 14, 1914, the following inoculations and control experiments were made, using as inoculum conidia from corn-meal cultures of the fungus isolated from a canker on August 3:

Three inoculations in slits in 2-year-old branches.
One control slit in a 2-year-old branch.
One inoculation in a slit in a 1-year-old branch.
One control slit in a 1-year-old branch.

The tree used was a 15-year-old specimen of the Missouri variety. The weather had been hot and moist and accordingly was quite favorable for the development of the fungus.

When the absorbent cotton was removed one week later it was evident that the inoculations had been successful. About the slits into which the conidia had been introduced the bark was blackened and sunken in a ring from 1 to 2 mm. in width, whereas only the cut surfaces of control slits were blackened. By October 7 the inoculated slits formed the central portions of rapidly growing cankers. At that time the fungus on the 2-year-old branches had developed until the blackened, sunken areas had attained lengths varying from

2 to 5 cm. and widths varying from 1 to 1.5 cm. The growth from the inoculation in the 1-year branch was even greater, the dead area being nearly 6 cm. in length. The control slits were beginning to heal.

On account of the writer's absence from Arkansas, the inoculated branches were not again examined until April 1, 1915. At that time the inoculated slit and control slit on 1-year-old twigs were not to be found, the twigs having been removed when the trees were pruned in March. The remaining cankers were the same size and apparently in the same condition as in the preceding autumn. The blackened bark presented the same sunken appearance and was still joined to the bark of the adjacent apparently healthy portions of the branch.

By May 10 there was no change in the general appearance of the cankers except that the blackened bark was no longer connected with the adjacent uninjured bark. There was a distinct fissure running entirely about the cankers, separating the blackened bark from the adjacent bark except at the extreme ends of the cankered area. This isolation of the dead bark was undoubtedly due to the fact that the branch had resumed growth, whereas the fungus had not. By May 21 the delimiting fissure was more pronounced, though the blackened bark was not wholly isolated. On this date the cankered branches were cut off, brought into the laboratory, and placed in moist chambers. At the end of 24 hours acervuli of the fungus appeared in all three of the cankers. Cultures from the conidia showed all the characters of *Glomerella cingulata*. Three of these cankers and one control were photographed and are shown in Plate V, figures 1, 2, and 3.

Another series of inoculations was made in Arkansas on June 18, 1915. The same technique was employed as in the experiments of 1914. The spores used in the inoculations were ascospores from cultures made from a canker on June 4 and conidia from cultures made from a canker on May 21. The plan of the experiment was as follows:

Three slits were inoculated with ascospores.
Three slits were inoculated with conidia.
Three slits were not inoculated.

This plan was carried out on three varieties—Ben Davis, Jonathan, and Missouri. The moistened cotton covering the slits was removed on June 23. Only 2-year-old branches were employed. The weather was cool and accordingly not very favorable to the growth of the fungus.

On July 8 all of the control slits were beginning to heal. In the case of the Ben Davis there was a band of dark sunken bark extending a distance of 2 mm. about each inoculated slit. About the

slits on the Missouri branches the dark sunken band was 3 to 4 mm. in width. There was no development whatsoever in the case of the Jonathan, either at this time or subsequently. On August 30 the black sunken bands about the slits on the Ben Davis branches were from 2 to 6 mm. in width, while those on the Missouri branches were slightly larger. The inoculated branches were not examined again until June 18, 1916. The cankers had not changed perceptibly. The chief thing to be noted was that there was no isolation of the blackened bark on three of the Ben Davis branches and on three of the Missouri branches. These branches, though of equal age, were not nearly so large as the others, which were rapidly growing water sprouts. The cankered areas on the water sprouts were being rapidly healed over by the formation of callus, and the blackened bark had been partly shed. The cankered branches were removed, brought to the laboratory, and placed in moist chamber for 24 hours. Acervuli of the fungus were produced in great abundance, and when reisolated in pure culture the organism was reidentified as *Glomerella cingulata*.

The question arises as to why quickly developing young cankers on vigorous young branches and water sprouts should not live and develop through the following season. Apparently this is what happens: The host has its period of most rapid growth in the spring. In the case of young branches and water sprouts, growth is particularly rapid at this time. The fungus, on the other hand, does not begin active growth until hot weather begins. Vigorously growing branches, such as water sprouts and young twigs, are able, therefore, through the growth of surrounding tissues to utterly isolate the young cankers and begin the formation of callus at their margins while the fungus is still dormant.

To test the effect of cool weather and to see if late infections would develop, Ben Davis and York Imperial branches were inoculated at Arlington Farm, Va., on October 5, 1915. The weather, though cool, was moist, but no perceptible growth was made about any of the 12 inoculated slits, nor was any growth made during 1916. On the contrary, the slits had entirely healed over by July 1, 1916.

Employing the same methods as in 1914 and 1915, the writer made several series of inoculations at Arlington Farm, Va., in 1906, using cultures of the fungus from a canker collected in Arkansas during the preceding autumn. In Table I the terms "margin intact" and "margin cracked" mean in the former case that the blackened bark of the canker is continuous with that of the uninfected portion of the branch and in the latter that it has been broken away from the bark of the uninfected portion. No separate notes were made concerning individual inoculations on the same limb, for the reason

APPLE BRANCHES SHOWING ARTIFICIALLY PRODUCED BITTER-ROT CANKERS AND ONE USED AS A CONTROL.

FIGS. 1 and 2.—Branches showing bitter-rot cankers artificially produced. Inoculations made through slits September 14, 1914. Removed and photographed May 27, 1915. Variety, Missouri. Bentonville, Ark.

FIG. 3.—A branch showing a control slit in the series of inoculations made September 14, 1914. Removed and photographed May 27, 1915. Variety, Missouri. Bentonville, Ark. For inoculated slits, see figures 1 and 2.

FIGS. 4 and 5.—Branches showing bitter-rot cankers artificially produced. Inoculated through slits July 13, 1916. Removed and photographed January 9, 1917. Figure 4, variety, Winesap; figure 5, variety, Jonathan. Note the large size of the cankers shown in figure 5.

that the resulting cankers usually showed no differences in their development.

Types of the cankers produced on the Winesap and Jonathan varieties are shown in Plate V, figures 4 and 5.

TABLE I.—*Results of inoculations of apple branches with bitter-rot fungus cultures at Arlington Farm, Va., in 1916.*

Apple variety and date of inoculation.	Age of branch.	Number of inoculated slits.	Width of blackened band.		Condition.	
			On Aug. 2.	On Aug. 29.	On Aug. 29.	On Nov. 20.
Ben Davis:	*Years.*		*Mm.*	*Mm.*		
June 28	4	3	3	3	Margins intact	Margins intact.
Do	4	3	2 to 5	5	do	Do.
Do	1	3	5 to 13	5 to 13	do	Margins cracked.
July 13	4	2	3	5	do	Margins intact.
Do	2	2	1 to 5	1 to 8	do	Do.
Do	3	2	4	5	do	Do.
York Imperial:						
June 28	1	4	1 to 5	1 to 5	Margins cracked	Margins cracked; callus formed.
Do	1	4	1 to 3	1 to 3	do	Do.
July 13	4	2	0	0	Healing	Healed.
Do	2	2	0	0	do	Do.
Do	4	2	0 to 1		do	Do.
Missouri:						
June 28	1	4	4 to 10	4 to 10	Margins intact	Margins nearly intact.
Do	1	4	0	0	Healing	Healed.
Do	3	4	0 to 1		do	Healing.
July 13	1	2	4	4	Margins intact	Margins nearly intact.
Do	4	2	3 to 5	8 to 10		Margins intact.
Do	4	2	15	15		Do.
Jonathan:						
June 28	1	4	0	0	Healing	Healed.
Do	1	4	0	0	do	Do.
Do	5	4	2 to 15	2 to 15	Margins intact	Margins intact.
July 13	4	2	30	30	do	Margins nearly intact.
Do	3	2	40 to 45	40 to 45	do	Do
Do	3	2	15 to 20	15 to 20	do	Do.
Grimes:						
June 28	1	5	1	1	Margins cracked	Healed.
Do	2	5	0 to 1	0 to 1	do	Do.
July 13	4	2	15	15	do	Margins cracked.
Do	4	2	2 to 15	2 to 15	do	Do.
Do	3	2	10	10	do	Do.
Winesap:						
June 28	4	5	2 to 15	2 to 15	do	Do.
Do	3	5	0	0	do	Healed.
July 13	4	2	5 to 10	5 to 10	do	Margins cracked.
Do	4	2	4 to 5	4 to 5	do	Do.
Do	4	2	30	30	do	Margins somewhat cracked.
Yellow Newtown:						
June 28	1	4	2	2	Healing	Healed.
Do	1	4	1	1	do	Do.
July 13	3	2	2	2	Margins cracked	Margins cracked; healing.
Do	2	2	2	2	do	Do.
Do	3	2	3	3	do	Do.

The following general notes on all the inoculations were made on November 20, 1916, and on January 9, 1917:

Ben Davis.—Except in the case of the 1-year-old branches, the margins of cankers are intact.

York Imperial.—Margins of cankered areas are separated from the bark of living portion of branch, and callus is forming.

Missouri.—Margins of cankers are intact except in the cases of very young branches (water sprouts).

Jonathan.—Cankers are very large on older branches, with small amount of cracking at margin.

Grimes.—Cankers have margins cracked; probably will survive.

Winesap.—Margins of cankers are somewhat cracked and much roughened; probably will not survive.

Yellow Newtown.—Margins of cankered areas are separated from bark of living portion of branch, and callus is forming.

On June 26, 1917, the following notes were taken:

Ben Davis.—Cankered areas irregularly cracked at margins in case of younger limbs. Layers of callus are forming. Those on older wood have margins intact. Acervuli are abundant.

York Imperial.—Slits have healed over. They are similar to the control slits.

Missouri.—Margins are irregularly cracked at the sides but not at the ends of the cankers. The cracks are not quite so large as in case of the Jonathan variety.

Jonathan.—Margins are cracked at the sides and separated from the living bark, from which callus is forming. There is no such separation, however, at the ends of the cankered areas.

Grimes.—Margins are cracked and a callus layer is forming. Acervuli are abundant.

Winesap.—The same as Grimes.

Yellow Newtown.—Lips of callus nearly meet. The dead bark is nearly all shed. The remnants of the old dead bark, however, produced acervuli and spores after 48 hours in moist chamber. The acervuli were very small and the spores few.

By September 19, 1917, the slits on the York Imperial and Yellow Newtown were healed over and the dead cankered bark completely eliminated. The cankers on the Ben Davis were persisting without any apparent change. In the case of the Missouri and the Jonathan varieties there was little or no new growth. Layers of callus were forming, but the old cankers with their dead bark still persisted. The former large lesions on the Grimes were nearly healed over, with elimination of most of the old dead bark. The lips of the layers of callus were nearly meeting. The Winesap cankers were similar to those of the Grimes except that the healing process had not been quite so rapid and hence more dead bark remained. In the case of all varieties except the York Imperial and Yellow Newtown, the fruit below the cankered limbs was infected with bitter-rot. The infected areas extended to the lowest limbs and were about 6 feet across. The infection was not carried to the fruit of adjacent trees, only the fruit of trees in which cankers had been artificially produced being affected. This shows how restricted is the dissemination of the disease and why it may become localized in certain trees.

As a result of these experiments it appears that the Ben Davis, Missouri, and Jonathan varieties are quite susceptible to the canker disease. The Grimes is apparently not quite so susceptible, but is

more so than the Winesap. The York Imperial and Yellow Newtown are very nearly immune. While on the two last-named varieties the fungus may begin the development of a canker, the reaction of the host is such that the growth of the fungus is soon checked and the incipient canker itself is later obliterated by the formation of callus. As these two varieties are the ones chiefly found in Virginia orchards and as their fruits, especially those of the Yellow Newtown, are susceptible, the writer believes that these inoculation experiments explain why bitter-rot cankers have not been found in that State.

It is also worthy of note that in these experiments the inoculations were eventually more successful on older branches than on 1-year-old twigs and water sprouts, though the growth was usually slower on the older branches. This is in accord with the writer's observations on naturally formed bitter-rot cankers.

The inoculations made in July were more uniformly successful than those made in June, doubtless owing to the fact that in July the temperature was much higher and the growth of the host more restricted.

These experiments and the writer's observations indicate that cankers in which the growth of the fungus is comparatively slow are apt to be much longer lived than those in which the fungus develops rapidly. This is particularly true in the case of the Givens, a variety which harbors more cankers than any with which the writer has come in contact. Cankers on Givens branches grow very slowly, but are exceedingly persistent.

Young vigorous-growing twigs are able, after the hot season which favors the bitter-rot fungus is over, to continue growth and by the formation of a callus layer to utterly isolate the mycelium of the fungus in the tissues which it has killed. This explains why the writer has not been able to find bitter-rot cankers on young branches.

It seems probable that another reason why cankers on branches of the Givens variety are so persistent is that this variety begins growth in the spring nearly two weeks later than most varieties. It is in the spring that the most vigorous growth of the apple occurs, and hence it is at this time of year than the branch is in the best condition to isolate the cankered areas and develop callus. The fungus, on the contrary, is not able to start growth until the weather becomes hot. This conclusion is drawn from the inoculation experiments of 1914 and 1915.

On January 9, 1917, three cankered branches of each variety inoculated in the 1916 experiments were cut off, brought into the laboratory, and placed in moist chambers for 48 hours. Masses of spores were produced from all cankers except those from the York Imperial and Yellow Newton trees. Cankers on the branches of

these two varieties were nearly healed over, and in the dead bark remaining the fungus was no longer alive.

Although these experiments seemed to show rather conclusively that the branches of the Yellow Newtown, the chief commercial apple whose fruit is susceptible to bitter-rot in Virginia, are resistant to the disease, it was also thought possible that the fungus found in Virginia might not be capable of causing cankers. This, however, proved not to be the case, as is shown by the series of inoculations listed in Table II. In fact, in these experiments the fungus isolated from Virginia fruits attacked the branches more vigorously than that isolated from bitter-rot cankers from Arkansas. The results of these inoculations did not differ materially from those of the previous experiments.

TABLE II.—*Comparison of results of inoculations of apple branches with bitter-rot fungus cultures from fruits grown in Virginia and in Arkansas, at Arlington Farm, Va., on August 21, 1916.*

Source of culture used.	Apple variety.	Age of branch.	Number of inoculated slits.	Width of blackened band.	
				On Aug. 29.	On Sept. 15.
		Years.		*Mm.*	*Mm.*
Virginia fruit	Ben Davis	2	6	1	6 to 20
Arkansas canker	do	3	6	1	1 to 2
Do	do	2	6	0	0
Virginia fruit	Missouri	2	4	2 to 3	3 to 10
Do	do	4	4	1	4 to 10
Arkansas canker	do	2	4	0 to 2	0 to 5
Virginia fruit	Yellow Newtown	1	4	1	4

The importance of cankers as sources of infection is also greatly increased by the enormous number of spores which a single canker is capable of producing in a season. The writer estimated that the number of conidia in one canker 7 cm. long by 2 cm. wide, not a large specimen by any means, was not less than nine millions. When one considers that during moist hot weather the production of spores may be almost continuous, he realizes that the number produced from a single canker during one season must be enormous.

SUMMARY OF KNOWLEDGE REGARDING BITTER-ROT CANKERS.

Knowledge of the bitter-rot cankers may be summarized as follows:

(1) Discovered by Simpson in 1902 and shown by Spaulding and Von Schrenk, in 1906, to be due to *Glomerella cingulata*.

(2) May occur perennially on older branches of susceptible varieties and may survive many years.

(3) Infections on younger branches develop rapidly but do not survive.

(4) Slow-growing cankers are more apt to survive.

(5) Varieties differ in susceptibility to the canker disease; the Yellow Newtown and York Imperial are nearly immune.

Since bitter-rot mummies and bitter-rot cankers are the chief starting points of the disease for the current season, a comparison between them as sources of infection is of interest. (Table III.)

TABLE III.—*Comparison of cankers and mummies as sources of infection.*

Cankers.	Mummies.
Relatively few except on very susceptible varieties..	May be few or many.
Spores produced in great quantity....................	Spores relatively few, owing to mummies being a poor culture medium.
A more or less perennial source......................	An annual source.
Directly injurious to the tree........................	Not injurious to the tree directly.
Fungus comparatively well protected from competition with other organisms.	Fungus not well protected.
Relatively hard to find and remove...................	Rather easily found and removed.
Located on older twigs or branches (not so advantageous).	Located among next year's fruits (advantageous).

CANKERS OTHER THAN THOSE OF BITTER-ROT.

In 1915 the writer (10) as the result of some work carried on in Arkansas in 1914, showed that the bitter-rot fungus may survive the winter in almost any cankered or dead part of an apple tree, including Illinois apple-tree cankers due to *Nummularia discreta*, dead tips of fruit spurs, dead parts of limbs injured by freezing or death of roots, branches injured by mechanical means, cankers caused by the pear-blight organism (*Bacillus amylovorus*), and twig cankers caused by the apple-blotch fungus (*Phyllosticta solitaria*).

In the case of those Arkansas and southern Missouri orchards in which the disease has been especially destructive over a period of years, it is comparatively easy to isolate the fungus from almost any dead portion of the trees. Such orchards which may have in addition bitter-rot cankers and bitter-rot mummies show how extremely destructive the disease can be and how very important are the agencies which carry it over from season to season. The fruit of orchards in which so many sources of infection survive the winter may be utterly ruined at the very first outbreak of the disease. These cases are, of course, exceptional ones; yet the writer has seen orchards the crops of which were totally ruined within a week, each apple averaging approximately 500 infections. In such cases, in which infection from wintering-over sources is so heavy, control by spraying alone is impossible.

Cankers due to various causes are important sources of infection in the Middle West, but they appear to play very little part in the infection of fruit in eastern orchards. The writer has found com-

paratively few cankers of any sort in eastern orchards susceptible to bitter-rot, and from those which he has found he has never been able to isolate the bitter-rot fungus. Pear-blight cankers from Yellow Newtown trees whose fruit had been badly damaged by the disease failed to produce fruiting bodies of *Glomerella cingulata*.

Blighted limbs of the Ben Davis, York Imperial, Missouri, Jonathan, Grimes, Winesap, and Yellow Newtown at Arlington Farm, Va., were sprayed on July 18, 1916, with a suspension of conidia in distilled water. Three branches of each variety were thus sprayed. On August 8 the branches were removed and placed in moist chambers. On August 10 sparsely fruiting acervuli were found on one branch each of Grimes, Jonathan, and Missouri; no signs of the fungus could be found on the remaining 18 branches.

LEAVES.

While leaves are of little importance as sources of infection and the writer has never found the fungus fruiting on them naturally, they are able to act at times as harboring places for the fungus.

Leaves of the Yellow Newtown from Virginia, even when in apparent health, will often develop acervuli of the fungus if kept in a moist chamber for a period of 12 to 36 hours, the leaves themselves becoming dark brown. In Arkansas, however, the writer was never able to find the fungus in the leaves of any of the varieties examined, namely, the Givens, Ben Davis, and Missouri.

Shear and Wood (15) in 1913 found that leaves of various hosts treated as above developed the fruiting bodies of the fungus. They state—

> From these and numerous other experiments of a similar kind performed at different times during the year with leaves from other plants, it appears that this fungus is quite generally present in the leaves of many plants in a dormant or innocuous condition awaiting some weakening of the host or other favorable condition which may give it an opportunity to develop.

The writer has many times during the spring and early summer examined the fallen leaves of the preceding year in an effort to find the fungus either fruiting on their surfaces or living within their tissues. Such efforts, however, have been uniformly unsuccessful. It is possible that the fungus, not being able to gain much headway in the living leaf on account of the vitality of the leaf itself, is kept from further development after the death of the leaf by the coolness of the weather prevalent at that time. Bacteria and molds not so sensitive to the cold may enter, however, and deprive the bitter-rot fungus of the food necessary for its existence and further development during the following season, even should it survive the winter in a dormant stage.

OTHER HOST PLANTS.

Shear and Wood (15) in 1913, after careful cultural and morphological studies in addition to cross-inoculation work with cultures from various hosts, gave the following list of 34 plants liable to attack by *Glomerella cingulata* (Stoneman) S. and V. S.

Brya ebenus (L.) DC. (Jamaica ebony.)
Caryota rumphiana Mart. (Palm.)
Cinnamomum zeylanicum Nees. (Cinnamon.)
Citrus aurantium sinensis L. (Sweet orange.)
Citrus decumana (L.) Murr. (Pomelo.)
Citrus limonum Risso. (Lemon.)
Citrus nobilis Lour. (Mandarin.)
Coffea arabica L. (Coffee.)
Costus speciosus (Koenig) Smith. (Spiral flag.)
Curculigo sp.
Eriobotrya japonica (Thunb.) Lindl. (Loquat.)
Ficus carica L. (Fig.)
Ficus elastica Roxb.. (Rubber plant.)
Ficus longifolia Schott.
Ginkgo biloba L.
Gleditsia triacanthos L. (Honey locust.)
Hedyscepe sp. = Kenita. (Palm.)
Ligustrum vulgare L. (Privet.)
Malus sylvestris Mill. (Apple.)
Mangifera sp. (Mango.)
Maranta arundinacea L. (?) (Arrowroot.)
Oxycoccus macrocarpus (Ait.) Pers. (Cranberry.)
Persea gratissima Gaertn. f. (Avocado.)
Phormium tenax Forst.
Pimenta acris (Swartz) Jostel.
Piper macrophyllum Swartz. (Pepperwort.)
Pitcairnia corallina Linden.
Psidium guajava L. (Guava.)
Ribes oxyacanthoides L. (Gooseberry.)
Rubus occidentalis L. (Black raspberry.)
Thea japonica (L.) Baill. (Camellia.)
Thea sinensis L. (Tea.)
Theobroma cacao L. (Chocolate nut.)
Vitis labrusca L. (Concord grape.)
Annona cherimola Miller. (Cherimoya.)
Crataegus sp. (Hawthorn.)
Rubus trivialis (cult.). (White dewberry.)
Smilax medica Schl. and Cham.
Vanilla planifolia Andrews. (Vanilla.)

Taubenhaus (17) in 1914 expressed the belief that *Gloeosporium officinale* E. and E., which he found caused a disease of the spicebush (*Benzoin aestivale* (L.) Nees) and of sassafras (*Sassafras variifolium* (Salisb.) Ktze.) in Delaware, is identical with the fungus which causes apple bitter-rot. He based his belief upon the fact that apples inoculated with the organism from the spicebush and sassafras developed the characteristic bitter-rot. He recommends the extermination of both the spicebush and the sassafras, so as to prevent them from harboring the bitter-rot fungus and carrying it to the apple.

The writer was never able to find the bitter-rot fungus on sassafras in Arkansas, though sassafras is very abundant in that section of the country. It is rather common, in fact, to find orchards surrounded by hedges of sassafras which have escaped destruction because of their nearness to the wire fences inclosing the orchards.

None of these plants as sources of infection compare in importance with mummied apples, apple cankers, or diseased apples. On none of these hosts, such as sassafras, raspberry, or hawthorn, which are commonly found in close proximity to orchards, does the disease become very destructive or epiphytotic, as it does upon the apple. Fur-

thermore, since the agency of birds or insects would be required for the infection of apples from such sources, only a few isolated fruits would probably be infected. Thus, while plants other than the apple would not be very important sources of infection in so far as the current year's fruit is concerned, provided the grower exercises ordinary watchfulness, they are of importance in that they may be a means of introducing the disease into an orchard which previously had been free from it and in which it may increase and eventually become very destructive.

In addition to those mentioned above, the fungus also occurs on the pear, apricot, tomato, sweet pea, and other plants, according to Halstead (8), Chester (5), and Sheldon (16).

INFECTED FRUITS OF THE CURRENT YEAR.

From the primary sources of infection previously discussed, especially mummies and cankers, the fruits of the current year become infected. These in turn become of the greatest importance as secondary sources of infection just as soon as acervuli begin to be produced in the diseased spots.

While the sources of infection, mummies, cankers, etc., which carry the disease over from season to season are of prime importance in that they initiate the disease, nevertheless, except in occasional orchards in which they are so prevalent as to be able to infect nearly every apple at the outset, the infected fruits of the current season are most important in the subsequent spread of the disease.

When the infected spot becomes a few millimeters in diameter, acervuli begin to form, and in a few days, if weather conditions are favorable, spores by the thousand may be washed down upon the sound fruits below. Thus a few infected apples may soon infect the entire crop of a tree.

When one considers that each infected apple becomes after a few days a new source of infection, and that the fungus grows and fruits very rapidly, he will have little difficulty in understanding why the disease can destroy an apple crop so quickly and will comprehend why it is so important that the application of spray for the control of the disease should be made before the first appearance of the disease. After the disease has become well established, attempts to control it by spraying not supplemented by the removal of infected fruits are usually ineffective if subsequent weather conditions are at all favorable to the development of the bitter-rot.

Often only a very few trees in an orchard will possess cankers and mummies in which the fungus has survived the winter. The fruit of these trees, then, is the first to become infected. From these infected apples the disease may be transmitted to the fruit of surrounding trees.

The transmission of the disease from susceptible varieties to rather resistant varieties may also occur through the medium of spores from infected fruits. Such destruction of the fruit of varieties normally resistant often occurs during years in which the weather conditions particularly favor the disease, especially if the trees are located in close proximity to susceptible varieties.

RELATION TO CONTROL MEASURES.

Under ordinary circumstances and in the average orchard, even in sections in which bitter-rot is an especially serious disease, control may be attained by means of spraying alone; but there are some orchards in which the wintering-over or primary sources of infection are so abundant that frequent sprayings, even if most carefully and thoroughly done, will not give adequate control.

The writer (10) in 1914 carried on control experiments in two orchards of this type in Arkansas and published his results in 1915. Both of these orchards had sustained in previous years heavy losses—from 20 to 50 per cent of the crop—in spite of frequent and thorough sprayings with Bordeaux mixture. The removal of mummies, cankers, and deadwood, supplemented by spraying, proved to be an efficient control measure and was so reported.

One of the orchards selected for the 1914 work was again used for the experiments of 1915. This orchard, consisting of about 400 trees, was given its regular annual pruning in March, and the pruners were instructed to pay special attention to the cutting out of all cankers and deadwood.

After the pruning was completed the orchard was again carefully examined and all cankers and deadwood which could be found removed. The pruners had done their work so well that few cankers and little deadwood could be found, though, of course, it was realized that to remove every canker and bit of deadwood was impossible.

The trees were sprayed with Bordeaux mixture on June 15. The disease became evident about July 15, and on July 19 small clumps of rotted fruits could be seen on many of the trees. On the last-named date the writer, with three helpers, picked off all the rotted fruits that could be found, in order to prevent their serving as sources of infection for the sound fruit remaining. The clumps of rotted fruits also served as indicators as to the location of the original sources of infection, which, when found, were removed. In this way many cankers of various sizes which had been missed at pruning time were removed. In fact, it may be said that this constituted practically a final clearing out of the sources of infection which had lived over from the previous season. In the case of three trees the percentage of infected fruit was so large that the entire

crop was shaken off. One tree, which appeared to be hopeless on account of the number of cankers and was otherwise of small value, was left untouched and recommended for removal.

As soon as a few of the trees were free from rotted fruit the spray outfit was started, so that each tree was sprayed almost as soon as the diseased fruits, mummies, and cankers were removed. This treatment so effectually checked the spread of the disease that comparatively few new infections occurred, although the season was an exceedingly favorable one for the development of the rot, the loss on many near-by orchards being 25 per cent and upward. The trees were again sprayed with Bordeaux mixture on August 7.

The varieties used in this experiment were the Jonathan, Ben Davis, and Givens, all of which, and more especially the last named, are quite susceptible to the disease. Yet at picking time the loss in the case of the Jonathans was only 4 per cent of the crop, while that of the other two varieties was but 1 per cent. In orchards in which during previous years the disease had caused about equally as severe losses as in this one, the losses during 1915 were at least 50 per cent, even in the case of those which had been sprayed. In many unsprayed orchards the crop was a total loss. In the spring of 1916 the same orchard was again examined for cankers and mummies and, as in the year previous, the first infected fruits and the sources of these infections were removed. The task was quite an easy one in 1916, as the work of the two preceding years had nearly eliminated the disease. Only two applications of Bordeaux mixture were made, one early in July and a second about August 1. Throughout the season the apples remained almost entirely free from rot, and examination of both dropped and picked fruit in the autumn revealed so few specimens of infected apples that the damage was considered negligible and impossible to compute on a percentage basis.

In 1917 the orchard had received two sprayings for the prevention of bitter-rot when visited by the writer on July 23. There was practically no rot except on the one tree from which little effort had been made to remove the cankers in previous years. This tree had been infested with so many cankers that it had been marked for removal, as already mentioned, but had finally been spared. The disease had gained considerable headway on this tree and every fruit appeared to be doomed.

GENERAL SUMMARY.

(1) Apple bitter-rot, caused by the fungus *Glomerella cingulata*, occurs in nearly all sections of the world where apples are grown, but reaches its high point of destructiveness in the more southern apple-growing sections of the United States.

(2) The causal organism survives the winter in certain parts of the host, which serve as sources of the infections occurring on the crop of the following year. It may survive in—

(*a*) Mummies.

Clinton, Hasselbring, Burrill and Blair, Alwood, Von Schrenk and Spaulding, Scott, and the writer showed mummies to be important sources of infection.

Apparently the fungus lives over in a mummy for only one year.

Both those mummies on the tree and those on the ground are important.

(*b*) Bitter-rot cankers.

The cankers were discovered by Simpson in 1902.

Von Schrenk and Spaulding proved them to be caused by the bitter-rot organism.

Cankers on young vigorous-growing branches do not survive till the next season. Those on older twigs, especially of very susceptible varieties, may survive for years. Different varieties show different degrees of susceptibility to the cankers. Certain ones, such as the Yellow Newtown and York Imperial, are nearly immune, though their fruit, especially that of the Yellow Newtown, is susceptible to the disease.

(*c*) Cankers other than those of bitter-rot.

Especially in western orchards, in which the disease has been particularly severe, *Glomerella cingulata* may be found in cankers and deadwood due to various causes.

(*d*) Leaves.

As first shown by Shear, the fruits of the causal organism may sometimes be found on leaves of the current year when removed and subjected to moist, hot conditions. The writer, however, has never been able to isolate the fungus from leaves of the previous season.

(*e*) Other host plants.

The fungus is able to infect many plants other than the apple.

(*f*) Infected fruits of the current year.

By conidia produced in these secondary sources of infection the disease is carried to sound fruits. This is the principal means by which the disease is spread after the initial infection.

(3) Spore dissemination is comparatively restricted and is carried on through the agency of rain, dew, insects, and possibly birds. Wind is a negligible factor.

(4) Varieties differ greatly as to susceptibility to the disease. Hot, moist weather favors infection.

(5) The removal of mummies and cankers is a practicable and efficient control measure when supplemented by spraying. This treatment gave control in orchards in which in previous years spraying alone had been uniformly unsuccessful.

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